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NWC TP 4922
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DESIGN AND EVALUATION OF THE FMU-90/B POINT-DETONATING DELAY FUZE FOR THE 2.75-INCH FOLDING-FIN AIRCRAFT ROCKET

by

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ABSTRACT. This report describes the steps involved in the design and evaluation of the FMU-90/B point-detonating delay fuze for the 2.75-inch folding-fin aircraft rocket (FFAR). Beginning with a summary of the performance requirements of this fuze, it discusses various phases of the development of the fuze. Formal laboratory evaluation and results of high-speed track and ground-launch tests of the fuze are summarized. The design, development, and qualification testing of a stab-initiated 50-millisecond delay primer is included.

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FOREWORD

Development of the FMU-90/B point-detonating delay fuze was performed by the Electromechanical Division, Fuze Department, during fiscal years 1969 and 1970. This effort was sponsored by the Naval Air Systems Command and authorized by AIRTASK A05-532-067/211-4/00000.

Released by
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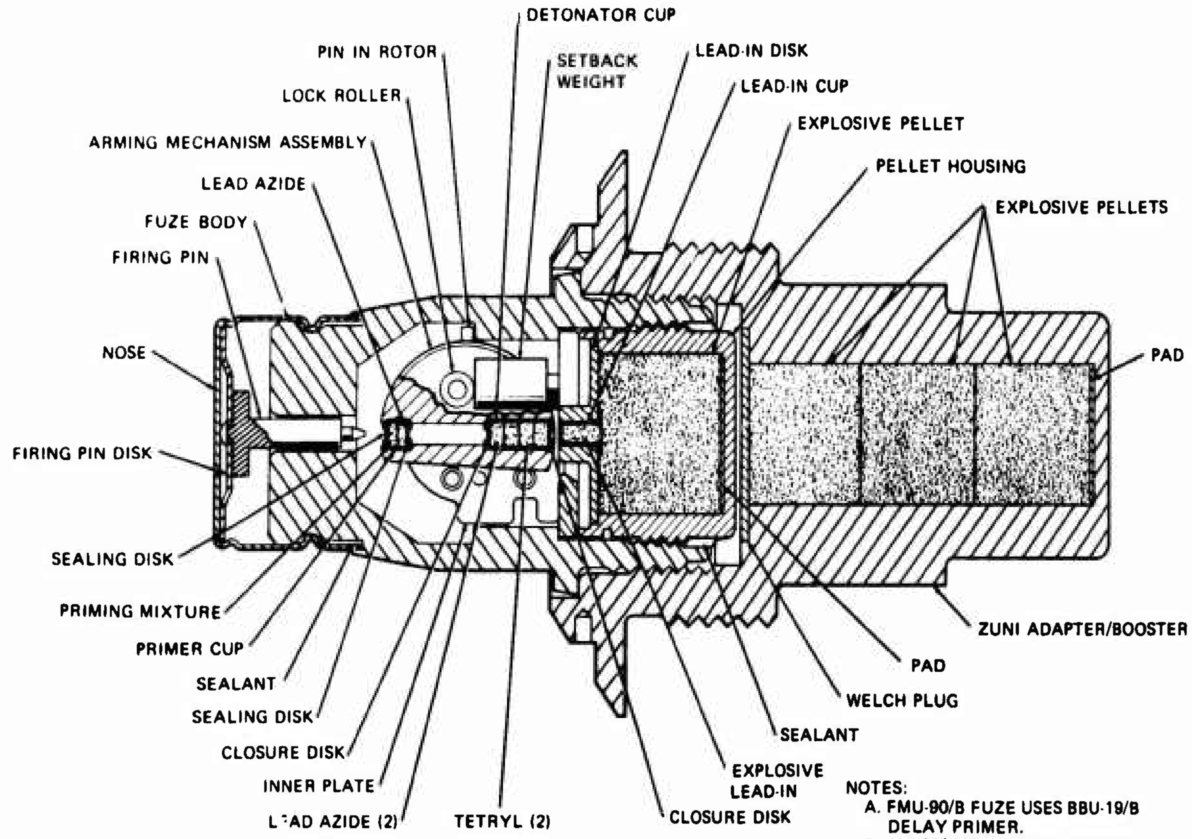

NOTES:
A. FMU-90/B FUZE USES BBU-19/B DELAY PRIMER.
B. MK 352 MOD 2 FUZE USES MK 125 MOD 1 PRIMER.
C. FMU-90/B REQUIRES SAME COUNTERBORE DEPTH BOTH ENDS ROTOR PRIMER-DETONATOR HOLE AND BBU-19/B DELAY PRIMER REPLACES MK 125 PRIMER.

FRONTISPIECE: FMU-90/B and Mk 352 Mod 2 Fuzes Shown as Installed in Adapter-Booster, Rocket BBU-15/B.

INTRODUCTION

To increase the applicability of the 2.75-inch folding fin aircraft rocket (FFAR), the Naval Weapons Center (NWC) has developed the FMU-90/B point-detonating delay fuze (Fig. 1). The FFAR rounds employing this fuze are capable of penetrating into fuze triggering media such as jungle canopy, brush, soft ground, or earthworks before the warhead detonates. Development of this fuze necessitated modifying the existing Mk 352 fuze design (Ref. 1) to accommodate a delay primer developed to be used in place of the instantaneous Mk 125 stab-initiated primer presently used. This allows the end-item option of either an instantaneous or a delayed action point-detonating fuze, with little difference resulting in manufacturing processes, and test and assembly procedures.

FIG. 1. FMU-90/B Point-Detonating Delay Fuze.

Like the Mk 352 fuze, the FMU-90/B fuze differs from other available fuzes for the 2.75-inch FFAR in its use of the pill-box nose design which was originally introduced in the Mk 188 fuze for the Zuni rocket, and which is intended to provide increased sensitivity on grazing impacts with the target. Also like the Mk 352 Mod 2 fuze, the FMU-90/B (1) employs a simplified one-piece

firing pin system in place of a multiple-piece firing pin system; (2) has improved nose and base seals; (3) incorporates features that provide high resistance to damage due to rough handling; (4) includes a safety feature which prevents assembly into a fuze body of an arming mechanism which is in the armed condition; and (5) can be used with the BBU-15/B adapter-booster in the Zuni Mk 24 and Mk 32 warheads. Because of its strong resistance to rough handling, this fuze has the capability of meeting the 40-foot drop test requirements in all orientations.

This report describes the steps involved in the design and evaluation of the FMU-90/B delay fuze. Included are the performance requirements of the fuze, a brief background on the steps in developing the fuze, results of qualification tests of the delay primer, a laboratory evaluation of the fuze, and the results of high-speed track and ground-launch tests. Installation, shipping, and handling of the FMU-90/B fuze are discussed in NWC TP 4923 (Ref. 2). A copy of the interim technical summary and status report concerning the fuze is included in the appendix.

BACKGROUND

In March 1969, NWC was requested by the Naval Air Systems Command (NAVAIR) to develop a delayed-action point-detonating fuze for the 2.75-inch FFAR. This fuze (Fig. 2) was to be a modification of the existing Mk 352 Mod 2 instantaneous fuze and was to include an approximately 50-millisecond delay primer in its explosive train. The development of this fuze consisted of two main phases–delay component development and modified fuze development.

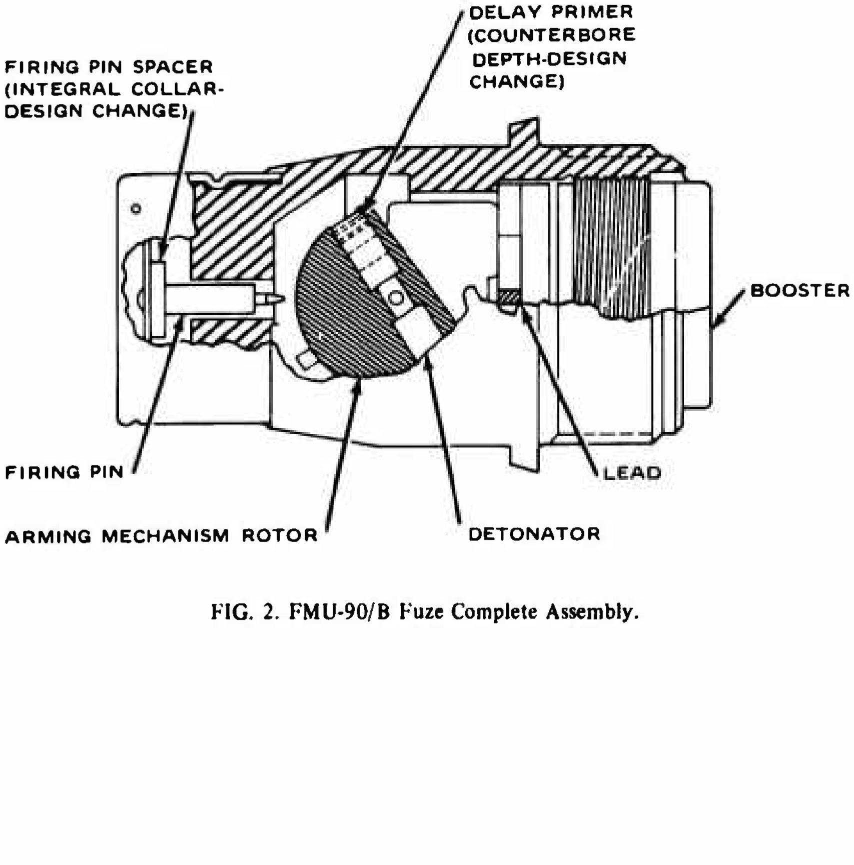

FIG. 2. FMU-90/B Fuze Complete Assembly.

DELAY COMPONENT DEVELOPMENT

The delay component development phase consisted of the following:

1. Generation of requirements and technical approach for the development of a delay primer
2. Determination of the feasibility of the delay primer development within the design constraints imposed by the existing fuze
3. Development and design qualification of the delay primer

The requirement to incorporate a delay of approximately 50 milliseconds into the explosive train of the Mk 352 fuze could have been accomplished by either of two approaches: (1) replace the existing stab-initiated instantaneous primer (Mk 125) with a new stab-initiated delay primer (to be developed) or (2) replace the existing flash-initiated instantaneous detonator (Mk 59) with a new flash-initiated delay detonator (to be developed). The first approach was chosen because the feasibility had been established for a stab-initiated delay detonator which possessed nearly the same input sensitivity characteristics as the existing Mk 125 stab-initiated primer which was being used in the Mk 352 fuze. The feasibility of such a stab-initiated delay detonator had been proved by the Bermite Division of Whittaker Corporation, and this delay detonator was readily available as a shelf item from that company. A decision was made to scale down the output of this delay detonator to make the output comparable with that of the Mk 125 primer, while maintaining the same input sensitivity characteristics, rather than to take the second approach which would have required the development of a new flash-initiated delay detonator with the same output characteristics as that of the Mk 59, but within the space limitations of the Mk 352 fuze.

It was also desirable to achieve a condition of maximum commonality between the Mk 352 fuze and its modified version, the FMU-90/B delay fuze. This made it necessary to impose additional requirements on the development of the new stab-initiated delay primer. These requirements dictate that the input sensitivity, the explosive output, and the maximum envelope diameter (0.161 inch) must remain the same as that for the Mk 125 primer. The restriction imposed on the overall length of the new primer was that it not exceed 0.500 inch. Some increase in length over that of the Mk 125 primer was expected because of the presence of the delay charge. Ultimately, the new delay primer, designated BBU-19/B, had an overall nominal length of 0.375 inch, which coincided precisely with that of the existing (and retained) Mk 59 detonator. Thus, the interests of simplicity, as well as those of commonality, were served by eliminating a requirement (as presently exists for the Mk 352 fuze) for different counterbore depths for primer and detonator.

MODIFIED FUZE DEVELOPMENT

The modified fuze development phase consisted of the following: (1) Laboratory and field evaluation of the modified fuze (with the new delay primer) consisting of environmental and safety tests performed in-house, high-speed track tests, and ground-launched all-up round tests; (2) preparation of NAVAIR documentation (technical data suitable for procurement of the modified fuze containing the new delay primer); and (3) recommendation for production release.

PERFORMANCE REQUIREMENTS

The FMU-90/B fuze will cause delayed high-order detonation of the warhead (to which it is assembled) upon impact with soft targets such as jungle canopy. The fuze will detonate the

warhead when striking targets at impact angles as small as 5 degrees and in about 50 milliseconds after impact.

The arming mechanism contained in the fuze is designed to perform the dual functions of (1) assuring safety by keeping the elements of the explosive train out of line prior to launch of the rocket and (2) providing effective warhead detonation by bringing the explosive elements into alignment after the rocket has been launched and has reached a safe separation distance from the launch vehicle. The fuze must not arm as a result of the effect of momentary setback forces (which could be encountered at any point in the logistic cycle), and it must not arm under sustained inertial forces of 13 *g* or less. However, it must be capable of arming throughout the entire thrust range that is normally encountered following launch of the rocket. The 2.75-inch FFAR usually provides at least 700 pounds of thrust, and this is sustained for a time sufficient to reach a safe separation distance from the launch vehicle.

PROGRAM OBJECTIVES

In order to produce a fuze that would meet the delay fuze performance requirements, two main objectives were established. One objective was to modify the existing Mk 352 fuze—and still maintain a maximum commonality of parts—only to the extent necessary to accept a delay primer in place of the instantaneous primer at the arming mechanism assembly level. The other objective was to design, develop, and qualify for production, a delay primer having the same outside diameter and the same initiation and output characteristics as the Mk 125 (instantaneous) primer, which it would replace for the modified design. The design goal for the primer delay time was 50 milliseconds, with the final nominal delay time and performance tolerances to be determined from the arithmetic average and standard deviation as calculated at the conclusion of the delay primer qualification program.

The two fuze design changes determined to be required to implement the main objectives of the program are briefly described in the following text.

An increased primer counterbore depth in the rotor was required to accommodate the greater length of the new delay primer (as compared with that of the old Mk 125 primer). This increased depth was the same as that required for the Mk 59 detonator (which is retained as the second member of the primary explosive train in the modified fuze); hence, a simplification of the overall design resulted because both the primer and the detonator holes can be identically dimensioned, bored, and inspected.

A collar, added to and integral with the firing pin shaft, was required to limit the normal travel of the firing pin and prevent penetration into the delay powder column of the delay primer assembly. This firing pin travel limitation was a firm design requirement imposed on the fuze by the nature of the delay primer functional design. Any penetration of the delay column could disturb or seriously impair the delay action. However, because the firing pin travel distance was immaterial for Mk 352 usage, the commonality objective was realized in this instance. That is, the collar had no effect on operation of the Mk 352 fuze but was indispensable to the reliable performance of the FMU-90/B fuze.

DEVELOPMENT AND QUALIFICATION OF BBU-19/B DELAY PRIMER

The fabrication and qualification of the BBU-19/B delay primer was performed under contract,[1] with technical direction and advice by explosive component specialists in the NWC Fuze Department, and proceeded in three consecutive phases: (1) preliminary development, (2) main development for firm-up of the design, and (3) design qualification and limited production. The plan for the last two phases was to design, develop, and fabricate 850 delay primers of an approved design. Of these, 350 would be used to perform qualification tests, 150 would be loaded into government-furnished arming mechanisms, and 350 would be used by NWC for laboratory evaluation.

PRELIMINARY DEVELOPMENT

Preliminary development, or feasibility determination, comprised a series of 20 test firings.[2] During this series, 118 experimental delay primers were expended. This resulted in a final design configuration envelope of 0.161-inch maximum outside diameter and an overall length of 0.375 ± 0.005 inch. The approximate amounts of pyrotechnic materials, and initiation and output increments necessary to meet the performance requirements were also established as a result of this preliminary development program.

MAIN DEVELOPMENT

The main development phase consisted of a series of 37 tests during which 587 individual delay primers, comprising several different internal metal parts and pyrotechnic composition configurations, were expended. Out of the first 397 primers tested, there were 38 test failures. The failures were due to nontransfer, which was determined to have been caused by incomplete burning of the A1A pyrotechnic material which was interposed (by design) between the NOL 130 primer initiation mix and the MKB delay powder blend. This problem was solved by the addition of a 15-milligram charge of FA-878 between the NOL 130 and A1A explosive materials (Fig. 3). FA-878 is a mixture of granular and powdery zirconium, lead peroxide, barium nitrate, and PETN. At the completion of the remaining 190 consecutive successful test firings (587 - 397 = 190) using the FA-878, it was decided that a sufficient number of units of identical design had been tested to justify fabrication of the production lot.

QUALIFICATION AND LIMITED PRODUCTION

For the qualification testing, 350 delay primers were separated into eight groups (see Table 1) and tested in accordance with test specification BW 1338.[3] For Groups I through VII, each primer was placed on an aluminum disk and initiated by a 2-ounce ball dropped from a height of 6 inches. Tests were conducted to determine the effects on the delay time of a plastic pin holder with and without a steel sleeve (firing bushing) (Group I and II), water immersion (Group III), temperature extremes (Group IV and V), and storage under temperature extremes (Group VI and VII) with subsequent firing at ambient temperature. Group VIII tests were

[1]Contract N00123-70-C-0041 to Bermite Division of Whittaker Corporation, Saugus, Calif. The testing results were reported by Bermite in *Qualification Program, 60-Millisecond Delay Primers*, 20 March 1970. (Final Technical Report TR702.)

[2]Contracts N62738-69-M-6633 and N62738-69-M-7350 to Bermite Division of Whittaker Corporation, Saugus, Calif. The testing results were reported by Bermite in letters of 14 and 24 July 1969; subjects: *Technical Information* and *Final Report*, respectively.

[3]Bermite Division of Whittaker Corporation. *Test Specification: Primer, 60-Millisecond Delay, Qualification Test Procedure for*. Saugus, Calif., Bermite, 3 December 1969. (BW 1338.)

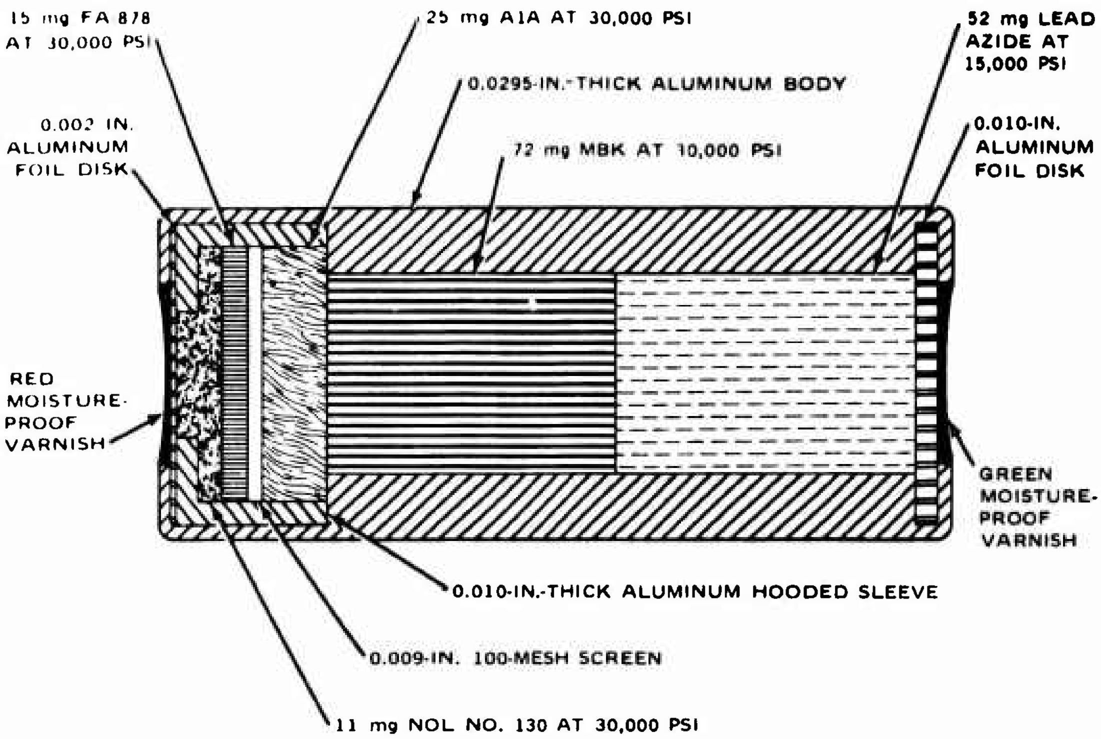

FIG. 3. BBU-19/B Delay Primer Configuration and Loading.

TABLE 1. Delay Primer Qualification Test Results.

Group	Type of test	No. of units	Temperature	Delay time, msec		Output, in.	
				Av.	σ	Av.	σ
I	Without bushing	25	Ambient	52	11	0.019	0.001
II	With bushing	50	Ambient	44	8	0.020	0.002
III	Water immersion	25	Ambient	45	9	0.020	0.001
IV	Temperature extreme	50	$-65^{\circ}F$	44	7	0.020	0.001
V	Temperature extreme	50	$+160^{\circ}F$	45	7	0.020	0.001
VI	Temperature storage	50	$-65^{\circ}F$	44	8	0.020	0.001
VII	Temperature storage	50	$+160^{\circ}F$	49	8	0.020	0.001
VIII	Impact sensitivity	50	Ambient	...	...	...[a]	...[a]

[a] By Bruceton analysis, the mean drop height using a 1-ounce steel ball, was 2.21 inches with σ = 1.05 inches.

impact sensitivity tests. The purpose of these was to determine the height at which a 1-ounce ball would have 50% probability of initiating the primer.

LABORATORY EVALUATION OF FMU-90/B DELAY FUZE

During February and March of 1970, laboratory evaluation tests (Fig. 4) were performed on 17 FMU-90/B fuzes (Ref. 3). Twelve of these underwent a full qualification program, and the other five were subjected to the 40-foot drop test.

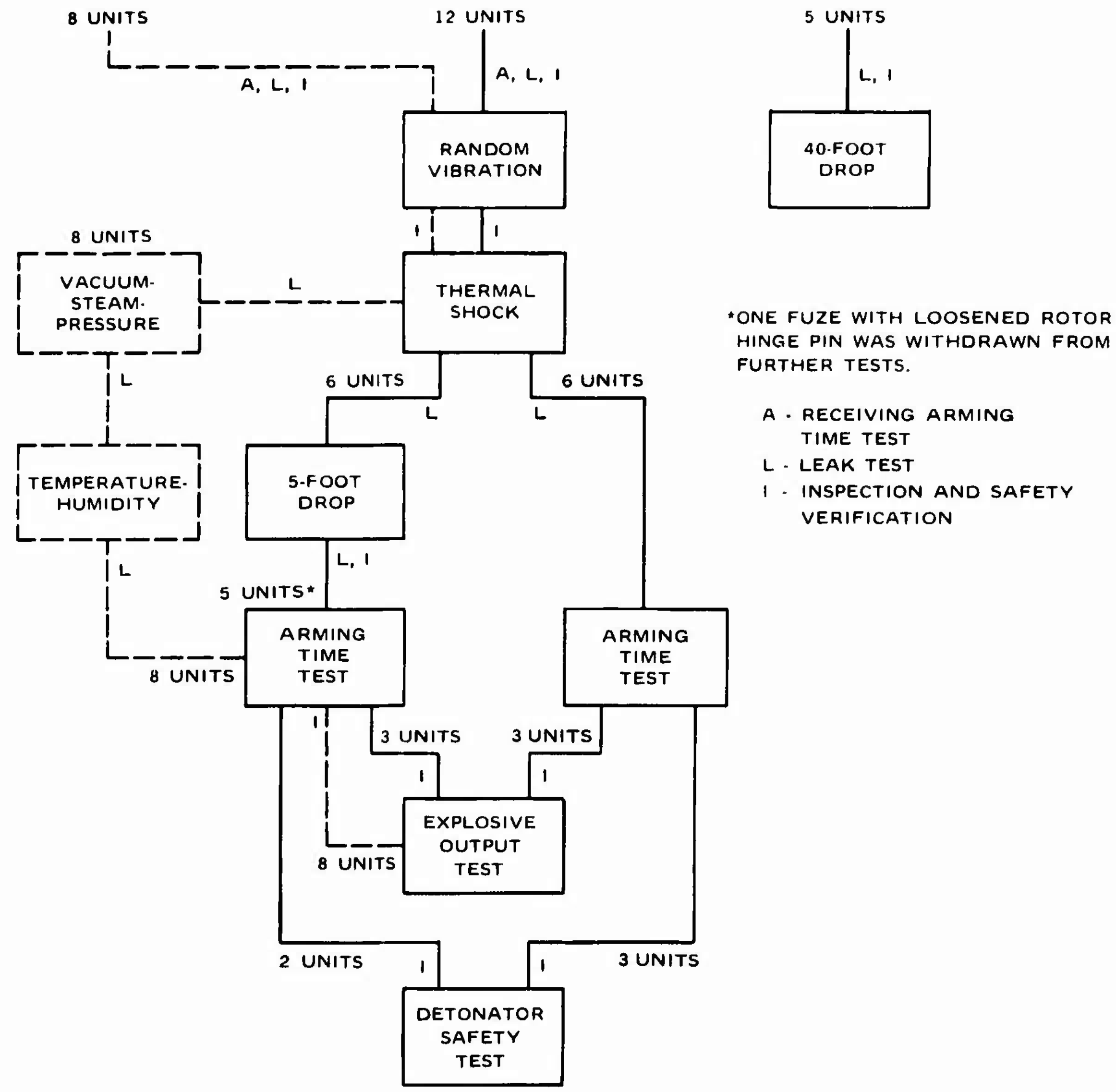

FIG. 4. Laboratory Evaluation Test Sequence of FMU-90/B Fuze.

QUALIFICATION PROGRAM

Before being subjected to the qualification tests, the 12 fuzes were checked for arming times, subjected to a leak test, and inspected for external defects and for rotor position. To check for arming times, each fuze was centrifuged, and its arming times were recorded for accelerations of 20, 40, 50, and 70 *g*. All the arming times were within the range of 0.88 to 2.2 seconds, and those measured at 40 *g* remained within the specification limits of 1.07 to 1.36 seconds.

For the leak test, the fuzes were submerged in a beaker of water that was placed in a bell jar in which the air pressure was reduced to 10 inches of mercury and held at that level for 5 minutes. No bubbles were observed, indicating that there was no fuze leakage. Each fuze was visually inspected for external defects and then inspected internally by radiographic means to determine the

position of the rotor. No external defects were found, and all rotors were in the safe position.

The 12 fuzes were subjected to random vibration in accordance with MIL-STD-810B, Method 514, Procedure II, Part 3, Curve AH. After an inspection and safety verification, in which it was ascertained that none of the fuzes had armed, the fuzes were subjected to Test 113 of MIL-STD-331, a thermal shock test. This was followed by a leak test in which no leaks were detected.

Six of the 12 fuzes were then given a 5-foot drop test (Test 111 of MIL-STD-331) and then leak-tested. No leaks were detected.

It was discovered, prior to the arming time test, that the rotor hinge pin in one of the fuzes had shifted partially out of its hole. A close examination of the radiographs showed that the shifting had taken place during random vibration of the fuze. Because the escapement was damaged in trying to extract the arming mechanism, testing of that fuze was discontinued. It was felt that the small amount that the pin shifted would not have prevented the mechanism from arming under otherwise normal test conditions.

CENTRIFUGE ARMING

The arming time tests consisted of demonstrating that the fuzes *do not* arm at 13 *g* and that they *do* arm in 1.07 to 1.36 seconds at 40 *g*. All 11 fuzes passed the test.

EXPLOSIVE OUTPUT

The explosive output tests demonstrated that the fuze explosive train operated properly. The fuze was armed, mounted (without the booster) to the inert warhead, and dropped through a 10-foot tube onto a steel surface. In each of the six fuzes (Fig. 3), all explosive elements up to and including the leads exploded after impact.

DETONATOR SAFETY

The static detonator safety tests were performed to demonstrate the safety of the explosive train. The tests were performed by drilling an appropriate hole in the fuze case so that a firing pin could be driven into the stab-initiated primer while the rotor remained in the safe position. The firing was initiated by dropping a steel ball down a rack and onto the end of a poised firing pin. All five fuzes passed the firing tests in accordance with the requirements of MIL-STD-331, Test 115.

FORTY-FOOT DROP TEST

The remaining five fuzes were subjected to a leak test and inspected for external defects and for rotor position before being given a 40-foot drop test. The 40-foot drop test was performed in accordance with Test 103 of MIL-STD-331, which requires a guided 40-foot drop onto a steel surface. After being dropped, the fuzes were inspected radiographically to ascertain that the explosive leads had not detonated and that the arming mechanism remained in the unarmed, or safe, condition. The five fuzes were determined to be safe to handle and dispose of. The primer and detonator of each fuze had not functioned, nor had the explosive leads been burned or detonated. Thus, all five fuzes passed the test.

SUMMARY OF LABORATORY TEST RESULTS

The one discrepancy found in the 17 fuzes tested was determined to be a fabrication quality failure and clearly not attributable to design inadequacy. Demonstrated statistical reliability of the design is 0.933 at 90% confidence.

ADDITIONAL ENVIRONMENTAL TESTS

Subsequent to the tests previously described, because of time delays incidental to the conduct of temperature and humidity cycling, an additional group of eight fuzes were subjected to the exposure of random vibration as specified in MIL-STD-810B, Method 514, Procedure II, Curve AH, followed by the MIL-STD-331 test procedures for thermal shock (Test 113), vacuum-steam-pressure (Test 106), and temperature-humidity (Test 105). These exposures were then followed by tests to demonstrate conformance with the procurement specification requirements on arming time and explosive output (see dashed lines of Fig. 4). All fuzes except one satisfactorily passed these additional tests. (One fuze failed to arm on the centrifuge.) Upon breakdown and inspection, a slight roughening or burring on the rotor was observed. This suggested interference that could have prevented *g*-weight setback and consequent mechanism arming (Ref. 4).

HIGH-SPEED TRACK AND GROUND-LAUNCH TESTS

Field testing of the FMU-90/B delay fuze was accomplished in two series of tests: the high-speed track tests, which were conducted at Holloman Air Force Base, New Mexico, and the all-up ground-launch tests, which were conducted at NWC, China Lake.

HIGH-SPEED TRACK TESTS

The track tests were conducted at the AFMDC high-speed test track at Holloman AFB. The objective of these tests was to establish the capability of the fuze to function properly in the delay mode upon impact with light targets such as could be encountered in tropical jungle canopies which were simulated by wooden targets varying in thickness from 0.125 inch to 6 inches. One target comprising dry mesquite bushes and two targets of 1-inch steel plate were also used.

The monorail test vehicle, shown in Fig. 5, was propelled by six high-velocity aircraft rockets (HVAR). The burn time for the rockets was about 1 second. This produced a typical peak acceleration of about 64 *g*, giving a velocity at target impact of approximately 1,500 feet per second. Two fuzes, a control fuze (containing no booster pellet) and a live test fuze, were used. Each was inserted into a 12-inch long, 2.75-inch diameter inert warhead, which in turn was mounted above the rockets on the front of the vehicle. Figure 6 shows Round 1 setup, with test fuze SN 25 in the upper position. The purpose of the shield between the two fuzes was to minimize the chance that detonation of the test fuze would affect the operation of the control fuze. Control fuzes in addition to live fuzes were employed in Rounds 1 through 6, 9, and 17 through 22. In

FIG. 5. Rear View of Monorail Test Vehicle Showing Rocket Motors.

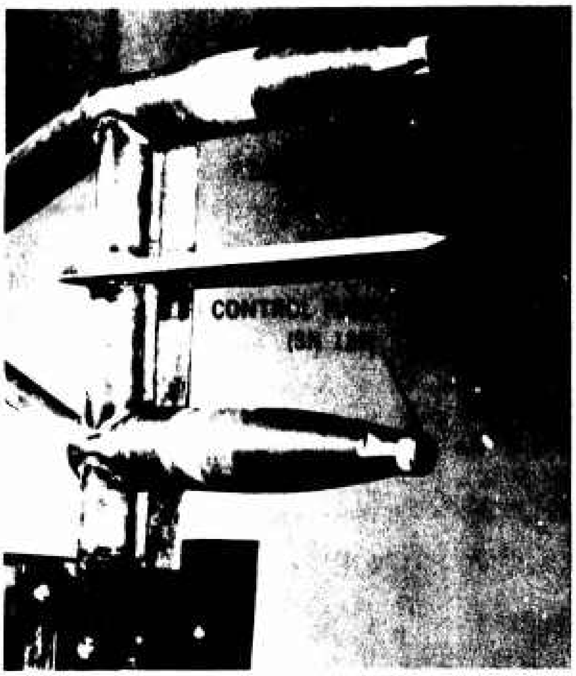

FIG. 6. Typical Test Setup Prior to Run.

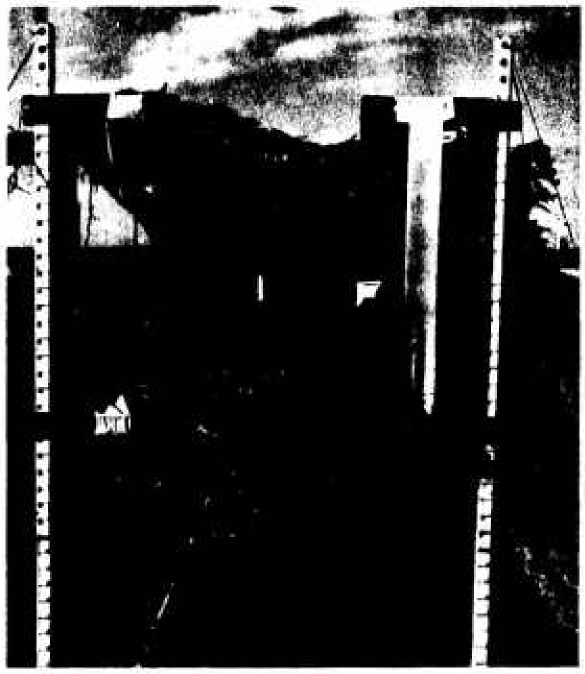

FIG. 8. Target Arrangement for Round 17.

FIG. 7. Target Arrangement for Round 1.

the other runs, only live fuzes were used.

When no control fuze was employed, only a single target was used; but when a test fuze and a control fuze were employed, then two targets, one for each fuze, were used for each round (sled run). For 19 of the 22 rounds, wooden targets of various thicknesses were used. The targets for Round 1, shown in Fig. 7, were made of 0.125-inch fiberboard. Other thicknesses of wood used were 0.5, 1.0, 2.0, 4.0, and 6.0 inches. All of the wooden targets were set at an impact angle of 90 degrees. The targets for Round 17, shown in Fig. 8, were dry mesquite bushes. The branch thickness in the area of fuze contact varied from 0.25 inch down to 0.03 inch. The targets for Rounds 21 and 22 were 1-inch steel plates. The plates for Round 21, as shown in Fig. 9, were hung vertically and presented an impact angle of 22.5 degrees. For Round 22. shown in Fig. 10, the plates were hung vertically but presented an impact angle of 90 degrees.

Results of the tests are shown in Table 2. For Rounds 1, 2, and 3, the annular gear was removed, and for Rounds 4 through 22 the fuzes

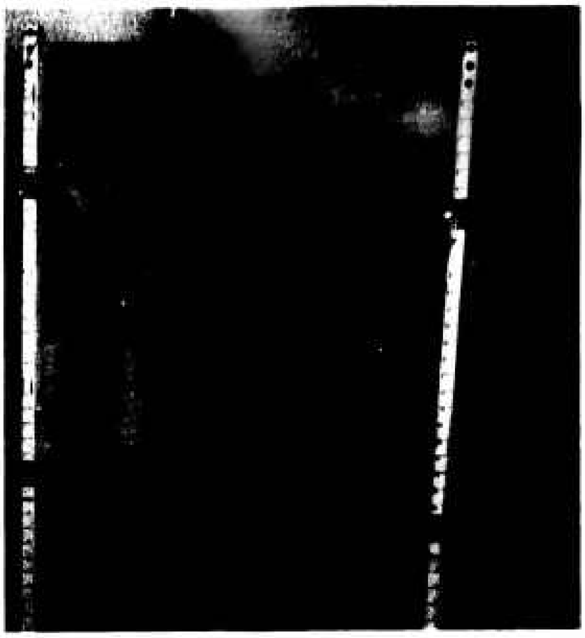

FIG. 9. Target Arrangement for Round 21.

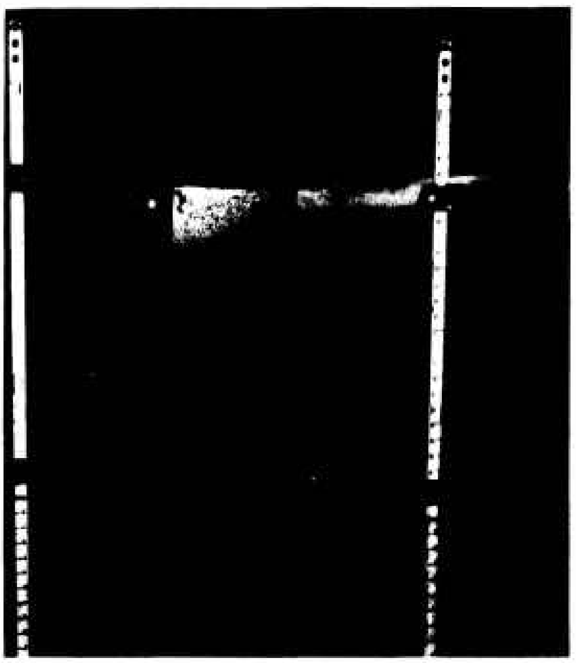

FIG. 10. Target Arrangement for Round 22.

TABLE 2. Results of Track Tests.

Round	Target		Sled speed, ft/sec	Fuze delay	
	Material	Thickness, in.		Distance, ft	Time, msec
1	Wood	0.125	1506	84	56
2	Do.	0.5	. . .[a]	. . .[a]	. . .[a]
3	Do.	0.5	1472	35	24
4	Do.	1.0	. . .[a]	. . .[a]	. . .[a]
5	Do.	1.0	. . .[a]	. . .[a]	. . .[a]
6	Do.	1.0	1481	5	3.4
7	Do.	2.0	1594	70	44
8	Do.	4.0	1469	25	17
9	Do.	4.0	1496	12	8.0
10	Do.	4.0	1476	3	2.0
11	Do.	4.0	1513	8	5.3
12	Do.	4.0	1530	5	3.3
13	Do.	0.125	1502	82	54
14	Do.	0.125	1490	68	46
15	Do.	0.125	1498	48	33
16	Do.	0.125	1458	67	46
17	Brush	. . .	1500	73	49
18	Wood	1.0	1434	64	45
19	Wood	6.0	1438	2	1.4
20	Wood	1.0	1483	45	30
21	Steel plate	1.0[b]	1480	34	23
22	Steel plate	1.0	1436	2	1.4

[a]Dud.

[b]Plates hung vertically at a horizontal impact angle of 22.5 degrees.

were prearmed. The average sled speed was measured by breaksticks placed at the target and 21.67 feet beyond. Delay time was calculated from the average sled speed and the observed detonation distance. To help determine detonation distance, witness plates of 4- by 8-foot sections of fiberboard were positioned trackside in the area of expected detonation. These served as backdrops for photography in addition to their primary purpose of registering fragmentation scars.

Figure 11 (Round 6) shows the effects of fuze impact on 1-inch-thick wooden target. Note the irrefutable evidence of fuze booster high-order detonation of the test fuze, and the appreciably deformed body of the control fuze. Beginning with Round 6, live test fuzes were in the lower position, and the control fuzes, when used, were in the upper position. Figure 12 (Round 9) shows the effects of fuze impact on a 4-inch-thick wooden target. Again the test fuze detonated high order. Note, too, the peeled pill box nose fairing and the very much deformed control fuze body.

Results of all impacts were satisfactory and indicated that an optimum delay mode function could always be expected against wooden targets of very thin structure, not exceeding 1-inch thickness. Beyond the latter thickness a shortened delay mode could be expected some of the time. The head-on impact with the 1-inch steel plates resulted in an instantaneous fuze function. The impacts with very thick wood (4 to 6 inches thick) also seemed prone to cause instantaneous (or nearly instantaneous) fuze functions.

FIG. 11. Results of Round 6 Impact on 1-Inch-Thick Wooden Target.

FIG. 12. Results of Round 9 Impact on 4-Inch-Thick Wooden Target.

GROUND-LAUNCH TESTS

The ground-launch tests used all-up 2.75-inch FFAR rounds containing M151 high explosive warheads with FMU-90/B delay fuzes installed. The rockets, containing Mk 4 rocket motors, were launched from a stationary tube launcher set at 5 and 10 degrees elevation. The main objective of the tests was to find out if the fuze-warhead combination would function properly upon impact with level desert terrain following ground launching at small quadrant elevations. A second

objective was to determine if delayed detonation would occur in case of a ricocheting round or a burrowing round.

Ten rounds were fired, eight at 10 degrees elevation and two at 5 degrees elevation. One of the two at 5 degrees was a dud. Performance data, given in Table 3, were based on the distance from rocket impact to the center of the warhead burst pattern formed on the ground. Figure 13 shows an example of the burst of a ricocheting round, and Fig. 14 shows an example of an underground burst. In Table 3, the ricocheting round as well as underground bursts show that the fuze-warhead combination functioned properly at these small impact angles.

FIG. 14. Example of an Underground Burst (Round 9).

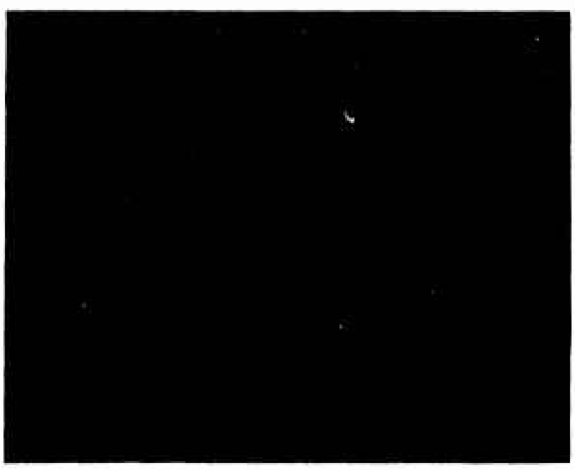

FIG. 13. Example of the Burst of a Ricocheting Round (Round 8).

TABLE 3. Results of Ground-Launch Tests.

Round	Impact angle, deg	Burst	Impact-to-burst distance, ft
1	10	Air	21
2	10	Air	40
3	10	Air	36
4	10	Earth	18
5	10	Air	45
6	10	Air	18
7	10	Air	21
8	10	Air	57
9	5	Earth	16
10	5	...[a]	...

[a]Dud.

SUMMARY

The main objectives of the FMU-90/B fuze development program may be briefly summarized as follows:

1. To modify the Mk 352 fuze in order to allow incorporation of a stab-initiated delay primer (in lieu of the Mk 125 stab-initiated instantaneous primer) with minimal design change to the fuze.

2. To develop and qualify (concurrently with the Mk 352 fuze modification) a stab-initiated delay primer, exhibiting the same input and output characteristics as the Mk 125 primer, and designated as the BBU-19/B delay primer.

3. To evaluate the performance of the modified fuze (FMU-90/B fuze) containing the newly developed and qualified delay primer (BBU-19/B delay primer) by laboratory and field testing.

These objectives were achieved by the satisfactory completion of the delay primer qualification program, the laboratory evaluation, the high-speed track tests, and the all-up ground-launch rocket tests utilizing the modified fuze.

RECOMMENDATION

The release for unlimited production of the FMU-90/B point detonating fuze, incorporating the BBU-19/B delay primer, is recommended.[4] Technical cognizance of this fuze should remain with the Naval Weapons Center through preproduction and the first production lot acceptance.

[4] Letter to NAVAIR from NWC, Ser 1928 dtd 11 May 1970; subject: Fuze, Point Detonating, FMU-90/B; recommendation, Release for Production.

Appendix

TECHNICAL SUMMARY AND STATUS REPORT OF THE FMU-90/B FUZE AND BBU-19/B DELAY PRIMER

The technical summary and status report reproduced in this appendix provided a brief interim program report, and were included in the final design review committee meeting held on 24 April 1970.

NAVAL WEAPONS CENTER CORONA ANNEX
CORONA, CALIFORNIA

TECHNICAL SUMMARY & STATUS REPORT
FMU-90/B FUZE & BBU-19/B DELAY PRIMER

TASK & SCOPE

By letter amendment dated 27 March 1969 to the basic AIRTASK No. A05-532-067/211-00000 which covered development, laboratory evaluation and release for production of the Mark 352 Mod 2 fuze a new requirement was added. This called for development of a delayed-action 2.75-inch FFAR PD fuze by: (1) modifying the design of the Mark 352 Mod 2 fuze to include an approximately 60-millisecond delay element (primer) in the primary explosive train (rotor); (2) evaluating and qualifying the delay element and the modified fuze; (3) obtaining and assigning nomenclature for formal identification of the delay element and the modified fuze; (4) furnishing and distributing NAVAIR documentation suitable for procurement of the modified fuze end-item; and (5) issuing a letter of recommendation on release for production.

Summary of Development,
Test & Evaluation

a. Technical data review for drawings peculiar to the delay fuze and the delay primer (FMU-90/B and BBU-19/B, respectively) was completed in accord with requirements of NAVAIRINST 4330.9. Similar review and approval for the drawings which are common both to this fuze and to the Mark 352 Mod 2 fuze had already been obtained.

b. The qualification program for the BBU-19/B delay primer has been satisfactorily completed. Delay primers totaling 527 were consecutively fired without a failure. This means a reliability number of not less than 0.995 with 90 percent confidence level. Subsequent consecutive firings without failures have brought this total to 678 and raised the reliability to 0.996 (minimum at 90% confidence level). An arithmetic average of approximately 53.5 milliseconds (with a standard deviation of 9.5 milliseconds approximately) appears to be a realistic value to be expected for the BBU-19/B delay primer function time.

c. The in-house laboratory evaluation has been satisfactorily completed except for a few test samples undergoing storage-type tests (which require 10 days of vacuum-steam-pressure followed by 28 days of temperature-humidity). The completed tests included random vibration, thermal shock, five-foot drop, forty-foot drop, detonator safety and explosive output. The fuze mechanism arming-time requirements were met and the seal integrity and water-proofness of the fuze assembly were demonstrated.

d. Track tests, conducted at the AFMDC high-speed test track at HAFB, N.M., were satisfactorily completed over the dates 9, 10, and 11 February. The objective of these tests was to establish the capability of the fuze to function properly in the delay mode upon impact with light targets such as could be encountered in tropical jungle canopies, but here exemplified by wood targets varying in thickness from one-eighth to six inches. One target comprising a dry mesquite bush and two targets of steel plate one-inch thick were also used. Results of all impacts were satisfactory and indicated that an optimum delay mode function could always be expected against wood targets of very thin structure up to those of one-inch thickness. Beyond the latter thickness a shortened delay mode could be expected some of the time. The head-on impact with the one-inch steel plates resulted in an instantaneous fuze function. The impacts with very thick wood (four to six-inches

thick) also seemed prone to cause instantaneous (or nearly so) fuze functions. The impact velocity was approximately 1500 feet per second in all cases. A tabulation summarizing the track test data appears at the end of this report.

e. Field tests were completed at G-1 Range, China Lake. These utilized all-up 2.75-inch FFAR rounds containing M151 (H.E.) warheads with FMU-90/B fuzes installed. The main objective of the tests was a simple and straight-forward demonstration of fuze-warhead function. Proper fuze-warhead function was required upon impact with level desert terrain following ground launching at small quadrant elevations. Elevations actually used were 10 degrees for the first 8 rounds and 5 degrees for the final two rounds. These elevations resulted in very high obliquity impacts. Actual impact angles were estimated to be approximately 10 degrees for the first eight rounds and about 5 degrees for the last two. The second objective was to establish that a delayed detonation occurred in case of a ricochet or burrowing round. A thorough examination of the impact and burst areas following the tests confirmed that all rounds except the last round had detonated, and showed further that their bursts had occurred at varying distances from the points of initial impacts. This established that the fuzes had functioned properly and in the desired delay mode. A tabulation of the test results below.

f. Further testing and evaluation is planned for the BBU-19/B delay primer as a component of the FMU-90/B fuze. These tests will be performed in-house. Their purpose will be to broaden and extend the margin of reliability of the delay primer itself and to more firmly establish the mean delay function time and the standard deviation. This will enable better definitization of performance requirements for future procurement of the FMU-90/B delay fuze. Specific induced environment exposures contemplated are random vibration, vacuum-steam-pressure and temperature-humidity, after which the BBU-19/B delay primer will be tested for delay time and explosive output.

FMU-90/B Fuze Ground Launch Test Firing Data Summary
(17, 18, 19 March 1970, G-1 Range, NWC, China Lake, Calif.)

Round	No. 1	burst	21	feet	beyond	point	of	initial	impact.	Air burst on ricochet
"	No. 2	"	40	"	"	"	"	"	"	" " " "
"	No. 3	"	36	"	"	"	"	"	"	" " " "
"	No. 4	"	18	"	"	"	"	"	"	Underground burst.
"	No. 5	"	45	"	"	"	"	"	"	Air burst on ricochet
"	No. 6	"	18	"	"	"	"	"	"	" " " "
"	No. 7	"	21	"	"	"	"	"	"	" " " "
"	No. 8	"	57	"	"	"	"	"	"	" " " "
"	No. 9	"	16	"	"	"	"	"	"	Underground burst
"	No. 10	DUD. Fuze broken off at base. Not recovered. Booster assembly remained in warhead.								

FMU 90/B FUZE TRACK TEST FIRING DATA SUMMARY
(9, 10, 11 February 1970, AFMDC High Speed Track, HAFB, N.M.)

Round & Fuze Numbers		Target Mat'l & Thk	Fuze Delay Time	Fuze Delay Distance	Detonation & Distance Observed by					Sled Speed	
					Naked Eye	Witness Plate	Cameras				
							I.R.P.	K38	FX		
1	25	1/8" wood	55.8	84	yes	yes	no	yes	yes	1506.10	
2	12	1/2" "	No Test.		Control fuze unarmed. Test fuze not armed at impact. DUD fuze to E.O.D.						
3	19	1/2" "	23.7	35	yes	no	yes	no	no	1471.86	control not armed
4	20	1" "	No Test.		Control fuze fired. Test fuze not armed at impact. DUD fuze to E.O.D.						
5	1	1" "	No Test.		Control fuze fired. Test fuze not armed at impact. Confirmed after E.O.D.						
6	15	1" "	3.4	5	yes	yes	no	yes	no	1481.31	
7	11	2" "	43.9	70	yes	yes	yes	no	no	1593.98	
8	13	4" "	17.0	25	yes	no	yes	yes	no	1468.65	
9	8	4" "	8.0	12	yes	yes	yes	yes	yes	1495.52	
10	23	4" "	2.0	3	yes	no	no	yes	no	1475.66	
11	14	4" "	5.3	8	yes	no	no	no	no	1512.72	
12	4	4" "	3.3	5	yes	yes	yes	yes	no	1529.70	
13	22	1/8" "	54.5	82	yes	yes	no	yes	no	1502.37	
14	18	1/8" "	45.7	68	yes	no	yes	yes	yes	1489.54	
15	21	1/8" "	32.7	48	yes	yes	no	yes	no	1497.71	
16	24	1/8" wood	45.9	67	yes	yes	yes	yes	no	1457.49	
17	17	Brush	48.7	73	yes	yes	yes	yes	no	1500.41	outside FX FOV.
18	5	1" wood	44.6	64	yes	yes	yes	yes	no	1434.44	
19	16	6" wood	1.4	2	yes	yes	no	yes	no	1438.32	
20	9	1" wood	30.3	45	yes	yes	yes	yes	no	1483.03	
21	3	1" St 22 1/2°	22.9	34	no	yes	yes	no	no	1480.37	outside FX FOV.
22	10	1" St 90°	1.4	2	yes	yes	yes	yes	yes	1436.41	

NOTES

a. Annular gear was removed for runs 1, 2, & 3 but mechanism was not prearmed; was prearmed for runs 4 & 5.

b. Recovery of run 5 test fuze dud after E.O.D. confirmed unarmed impact. c. Run 6 & subsequent test and control fuzes were prearmed. d. Average sled speed as measured from target to 21.67 feet beyond.

e. Delay time calculated from average sled speed & observed detonation distance. f. Cameras used: infrared Polaroid (I.R.P.), K38, & Fastax (FX) @ 3500 frames per second. g. Fuze delay time is in milliseconds & detonation distance is in feet; average sled speed is in feet per second.

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